# EXTENDING PHENOLIC RESIN PLYWOOD GLUE WITH CORN GLUTEN AND SOYBEAN MEAL

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Previous investigations at the U. S. Regional Soybean Industrial Products Laboratory on the modification of phenolic plastics with soybean meal suggested that soybean meal or other proteinaceous material could be used advantageously in extending phenolic resin plywood glues. A successful lower cost waterproof glue would be a large factor in increasing the use of exterior-grade plywood. The earlier plastics investigations had demonstrated that excellent water resistance can be attained in formulas containing one-third phenolic resin and two-thirds wood flour and protein materials which have relatively high water-absorbing capacities.

Preliminary work on mechanical mixtures of commercial plywood resins and soybean meal showed them to have insufficient flow for satisfactory glued joints. Several methods are available for improving the flow properties of a combination of resin and protein mixtures. These are: (1) addition of a plasticizer; (2) modification of the protein by a hydrolytic treatment; (3) use of a resin of low molecular weight; and (4) combination of suggested methods. Of the several methods, (3), use of a low-molecular weight resin, proved to be the most practical. This circular describes the preparation of a special type of low-molecular weight resin to be used in making up the glue and the method of combining it with proteinaceous materials. Laboratory data showing the adhesive strength and water resistance of the glue are also given. These data indicate that the product is ready for mill trial.

## Preparation of the Glue

### A. Preparation of the Resin

The resin used in preparing the glue is a simple type of phenolic resin with a ratio of one mole of phenol to one and one-half moles of formaldehyde; six grams of sodium hydroxide for each mole of phenol are used as a catalyst. For the preparation of a small quantity of resin (around 1 liter), the reaction can be carried out in a three-necked round-bottom flask heated on a steam bath. For the preparation of larger quantities

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(four liters or more) of the resin, the reaction vessel should be jacketed for steam heating and cooling with water. The reaction is exothermic and proceeds rapidly after reaching a temperature of about 70° C.; it would be dangerous without a cooling system for its control. The ratio of phenol to formaldehyde may be varied somewhat without affecting the results, but one mole of phenol to one and one-half moles of formaldehyde gives good results and has been used in all of this work.

The chemicals are mixed together and reacted until the temperature reaches 95° to 100° C.; then the reaction product is cooled slowly to room temperature. The total time for reacting and cooling should not exceed 60 minutes. The resin thereafter should be kept in a cool place, preferably under refrigeration, to retard further reaction, although storage at room temperature for several weeks does not seriously affect the properties of the resin. The solids content of the resin as thus prepared is 53 percent.

B. Proteinaceous Materials

The experimental work was carried out with corn gluten and soybean meal, both of which were found to be satisfactory.

The corn gluten was of the type frequently referred to as "Merco" gluten, because it is recovered with the Merco or a similar centrifuge. The gluten used in this work contained 55 to 60 percent protein.

The soybean meal was a byproduct of the pilot plant used by this Laboratory for making refined soybean protein. It contained 50 to 55 percent protein and essentially no water-soluble fraction, since this was removed in the process of refining the protein. Products similar to this are available on the market.

To improve the spreading characteristics of the glue, linseed meal is used in the glue formula in proportions up to 25 percent of the weight of the corn gluten or soybean meal. The linseed meal is the ordinary commercial product produced in hydraulic or expeller presses. The linseed cannot be used alone successfully as an extender for the resin since its very high water-absorbing properties would result in too great dilution of the glue.

C. Formulation of the Glue

Many formulations, using different materials of varying protein content and different resin-meal ratios, are possible. The following two formulas illustrate the preparation of the glue.

Formula 1: 1 part proteinaceous material to 1 part resin
300 g. Liquid phenolic resin (53 percent solids)
120 g. Soybean meal
39 g. Linseed meal

40 g. Carbon disulfide
100 g. Ethyl alcohol (95-percent)
338 g. Water
This formula makes a glue having 34 percent solids.

Formula 2: 2 parts proteinaceous material to 3 parts resin
750 g. Liquid phenolic resin (53 percent solids)
225 g. Corn gluten
40 g. Linseed meal
40 g. Carbon disulfide
300 g. Water
175 g. Ethyl alcohol (95-percent)
This formula makes a glue having 43 percent solids.

The glues are prepared with a solids concentration of 30 to 50 percent, depending on the resin content of the glue, the spreading equipment availabke, and the kind and thickness of veneer to be spread. The resin, prepared as described under A, and the proteinaceous meals specified in the formula, are mixed in a conventional glue mixer. After the mix begins to thicken, the remaining solvent and carbon disulfide are added, and stirring is continued until the glue becomes smooth. The glue is allowed to stand for 10 to 12 hours after mixing to allow time for the reaction with carbon disulfide and for the viscosity to increase to a spreading consistency. The finished glue will have a working life of several days.

The carbon disulfide is used because it reacts with the protein and thus decreases water-absorbing capacity. Since the minimum requirement has not been determined, the amount specified in the formulas represents an excess of this reagent.

Formulas 1 and 2, with a number of variations in the ratio of resin to proteinaceous materials, have been tested on both hard and soft wood veneers in the laboratory. The glue was spread with a conventional glue spreader having rubber-covered corrugated rolls, and the tensile tests were made on a standard Riehle Automatic Plywood tester. Tables 1, 2, 3, and 4 present the laboratory results obtained for plyw ood test pieces prepared with glues containing different ratios of resin to proteinaceous materials. The spread is expressed in pounds of dry solid glue per 1,000 square feet of single glue line, and each recorded shear value or wood failure is the average of five breaks. A 3-hour boiling test was used on the hardwood samples to determine their resistance to water; the test pieces were broken while wet. This test is similar to the boiling test used in the Army-Navy Specification for Aircraft Flat Panel No. AN-NN-P511b, except that a 3-ply panel was used in place of the 7-ply described in the specification. The specification calls for minimum breaks of 310, 230, and 150 pounds per square inch, respectively, for birch, mahogany, and poplar. The Douglas fir samples were subjected to the wet-and-dry cycle test. This test, which is part of the specification used for Douglas fir exterior plywood, consists of 48 hours' soaking at

70° F. and 8 hours' drying at 145° F., 16 hours' soaking and 8 hours' drying at the same temperatures, a third cycle like the second, another soaking for 16 hours, and breaking while wet. Under these conditions the break must show a minumum of 60 percent wood failure. The Douglas fir panels were also 3-ply, and were made by pressing together the glued veneer (1/10 inch thick) under 175 pounds per square inch for 8 minutes at 320° F. The moisture content of the assembled veneer at the time of pressing was between 8 and 12 percent. This moisture content was obtained in the laboratory by a partial drying of the spread veneer before assembling.

Table 1.- Glue spreads, and shear values after boiling 3 hours in water, for 3-ply panels made of hard woods and phenolic-resin glue modified with corn gluten

| Resin-gluten ratio | Spread lb./1,000 sq. ft. | Kind of hard wood | Shear lb./sq. in. |
|---|---|---|---|
| 2:1 | 9.7 | Birch | 400 |
| 2:1 | 11.0 | " | 400 |
| 2:1 | 11.9 | " | 427 |
| 2:1 | 12.3 | " | 422 |
| 2:1 | 13.2 | Poplar | 250 |
| 2:1 | 15.0 | " | 258 |
| 1:1 | 11.0 | Birch | 345 |
| 1:1 | 11.5 | " | 355 |
| 1:1 | 11.9 | Mahogany | 400 |
| 1:1 | 12.3 | " | 432 |

Table 2.- Glue spreads, and shear values after boiling 3 hours in water, for 3-ply panels made of hard woods and phenolic-resin glue modified with soybean meal

| Resin-soybean ratio | Spread lb./1,000 sq. ft. | Kind of hard wood | Shear lb./sq. in. |
|---|---|---|---|
| 2:1 | 9.3 | Birch | 436 |
| 2:1 | 10.1 | " | 450 |
| 2:1 | 12.8 | " | 403 |
| 2:1 | 9.3 | Mahogany | 357 |
| 2:1 | 10.1 | " | 425 |
| 2:1 | 11.0 | " | 428 |
| 1:1 | 10.6 | Birch | 390 |
| 1:1 | 11.9 | " | 327 |
| 1:1 | 12.3 | " | 388 |
| 1:1 | 10.1 | Mahogany | 357 |
| 1:1 | 11.0 | " | 322 |
| 1:1 | 12.6 | " | 359 |
| 1:1 | 11.0 | Poplar | 253 |
| 1:1 | 11.9 | " | 247 |
| 1:1 | 13.1 | " | 257 |

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Table 3.- Glue spreads, and percent of wood failure in breaking after wet-and-dry cycles, for 3-ply Douglas fir panels made with phenolic-resin glue modified with corn gluten

| Resin-gluten ratio | Spread lb./1,000 sq. ft. | Percent wood failure |
|---|---|---|
| 2:3 | 12.7 | 99 |
| 2:3 | 9.6 | 96 |
| 1:2 | 9.0 | 84 |
| 1:2 | 9.9 | 83 |
| 1:2 | 13.4 | 85 |
| 1:2 | 14.0 | 86 |

Table 4.- Glue spreads, and percent of wood failure in breaking after wet-and-dry cycles, for 3-ply Douglas fir panels made with phenolic-resin glue modified with soybean meal

| Resin-soybean ratio | Spread lb./1,000 sq. ft. | Percent wood failure |
|---|---|---|
| 1:1 | 12.0 | 94 |
| 1:1 | 13.2 | 97 |
| 1:1 | 14.0 | 88 |
| 2:3 | 7.9 | 63 |
| 2:3 | 8.5 | 48 |
| 2:3 | 9.6 | 90 |
| 2:3 | 10.1 | 87 |
| 2:3 | 10.6 | 76 |



The glue spreads shown in these tables varied between 8 and 13 pounds of dry solid glue per 1,000 square feet of single glue line. In commercial practice the glue spreads for phenolic-resin glues would be in the range of 10 to 14 pounds; thus it can be seen that the glue spreads used were well within practical limits. In examining the results in Tables 1, 2, 3, and 4, it will be observed that all test panels with glue spreads above 9 pounds per 1,000 square feet passed the usual specifications for waterproof glues.

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